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EVALUATION OF USE OF RAMP RADAR DISPLAY IN AIR TRAFFIC CONTROL TOWERS

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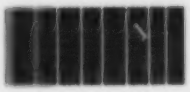

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Evaluation of Use of RAMP Radar Display in Air Traffic Control Towers

by

M. Hanner, R.V. Kruk and D.W. Runnings

CAE Electronics Ltd.

March 1991

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16. Abstract

The Radar Modernization Project (RAMP) Display Site Equipment (DSE) operating and display characteristics were evaluated with respect to tower controller task and information requirements. In general, the RAMP DSE is far superior to current tower radar displays and can access all information required by tower controllers. The major problem with RAMP DSE is that it has not been optimized for control tower operations.

The analysis showed that for the optimization of RAMP DSE in tower operations, three areas can be improved: display content, keyboard, and software user interface. First, the content is excessive and at times redundant for control tower operations. Reducing the tag content and providing a simpler present position symbol set would make the display easier to read. Since tower operations are a combination of "heads up" (out the window) and "heads down" (radar scan), making the keyboard simpler and smaller will allow more time for "heads up" as opposed to time spent on working the keyboard. With a keyboard change, the software user interface could be simplified to allow immediate access to relevant information through the use of dedicated function keys.

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16. Résumé

La recherche dont il est rendu compte a consisté à comparer les caractéristiques fonctionnelles du système d'affichage RAMP à celles que devrait avoir un système pouvant convenir aux besoins d'une tour de contrôle. Elle a montré que, de façon générale, le système d'affichage RAMP est très supérieur à ceux qui équipent couramment les tours de contrôle, étant donné qu'il permet d'afficher toutes les informations requises par les contrôleurs. Par contre, le système RAMP n'a pas été optimisé pour convenir aux opérations de contrôle du trafic aérien.

Trois possibilités d'amélioration se présentent, d'après les analyses faites : le contenu des blocs de données, le clavier et l'interface homme-machine. En plus d'être excessif, le contenu est parfois redondant pour les besoins du contrôle de la circulation aérienne. Pour rendre ce contenu plus facile à interpréter, il suffit de le rendre plus succinct et de simplifier le groupe de symboles représentant la position instantanée. Étant donné que, par leurs fonctions, les contrôleurs passent constamment d'une attitude tête haute (voir ce qui se passe à l'extérieur) à une tête basse (voir ce que l'écran affiche) et vice versa, simplifier le clavier et le rendre moins encombrant déboucherait sur un système que les contrôleurs pourront utiliser dans une attitude plus souvent tête haute que tête basse. La modification du clavier facilitera en outre le dialogue homme-machine du fait que l'opérateur n'aura plus que des commandes dédiées à actionner pour accéder à l'information qu'il désire.

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The authors also gratefully acknowledge the guidance of Mr. Roy Nishizaki of the Transportation Development Centre, Policy and Coordination Group, Transport Canada.

SUMMARY

1. Background

The Radar Modernization Project (RAMP) display site equipment (DSE) will provide tower controllers with a new digitized radar display. The primary objective of the project was to determine what information is required by tower controllers and how to best present that information.

2. Task and Information Analysis

In order to perform the task analysis and determine RAMP information requirements for tower operations, four airport control towers, representing different traffic densities and complexities, were visited and multiple information sources were reviewed. Task related information was extracted from tower controller job descriptions, manual of operations (MANOPS), training manuals, and tower related task analysis information.

3. Tower Controller Task Analysis

After completing visits to the airport control towers and reviewing the documentation, the relevant activities for the tower controller were listed. These activities can be divided into four categories as follows:

(a) Control of airport traffic

- Maintain traffic separation
- Coordinate traffic flow
- Plan traffic flow

(b) Equipment activities

- Operate equipment

(c) Supplementary activities

- Relay information
- Provide navigational assistance
- Weather observations

(d) Special situations

- Provide alerts
- Emergency response
- Respond to unsafe conditions

4. Tower Control Requirements Analysis

Based on the review of documentation and discussions with tower staff across Canada, the display needs for control of airport traffic are relatively straightforward. For each target affecting their airspace, tower controllers want to know:

- Position (with sufficient geographic information)
- Altitude
- Speed
- Weight class
- Identification (callsign).

Additional information such as vertical velocity may be useful from time to time. The RAMP DSE has the ability to provide all this data.

Since even relatively simple target tags may overlap in high traffic density situations (especially near the runways), and since tower controllers cannot spend significant periods of time "heads down" on the display to interpret complex data, the baseline condition should be the display of the minimum necessary information. A limited set of additional data could be brought up on demand.

The time spent operating the display should be kept to a minimum. The information and functions available need to be filtered to reduce complexity of operation and of display interpretation. The RAMP DSE should be strictly an information source and manual interaction with the system should be kept to a minimum.

5. Equipment Operation

The brightness adjustments appear to adequately cover the range of ambient lighting conditions (sunlight to nighttime operations).

The keyboard is excessively large and complex. An alternative keyboard or control unit that is reduced in size and functions could greatly help with space restrictions, time to access functions, and training. The requirement for accessing a function often occurs when the controller is busy and traffic density is high. Operating in a "heads down" mode during this period could potentially compromise tower operations.

Functions which are most naturally served by analog controls (such as display brightness) must be accessed through the keyboard. Sequencing through several levels of a menu to access a function is extremely time consuming and a "heads down" activity.

6. Analysis of Functions

A number of RAMP functions are superfluous to the tower control task. The data and functions available in RAMP were analyzed and broken down into functions which (in our opinion) should be deleted, functions which will only be used during system setup, and functions that will be used regularly by tower controllers.

7. Information Display and Content

The information content is too great in the present position symbols (PPS) and the data tags. The standard RAMP DSE uses 22 unique PPS symbols. These symbols are difficult to discriminate unless they are near their full size of 6.3 mm. The PPS set can be reduced to five symbols for tower controllers: three easily distinguishable geometric symbols for weight class with the splat (*) for uncorrelated targets and question mark (?) for coasting targets. If primary surveillance radar (PSR) and secondary surveillance radar (SSR) discriminations are required, then the symbols can be either filled or unfilled.

Data tags contain both excessive and redundant information, which increases clutter. For the tower controller, a basic tag should include aircraft identification (ACID), altitude, and groundspeed. An alternative field tag should retain ACID and could include items such as vertical velocity, aircraft type, and any special notes. For visual flight rule (VFR) traffic passing through the zone (i.e., no flight plan), a quick tag function would allow the controller to monitor these aircraft with ACID as well as PPS on the display.

8. RAMP DSE Emulation

In order to evaluate some of the proposed changes to the PPS set and tag information, the RAMP DSE display for Dorval tower was emulated, and the standard RAMP DSE presentation was compared with a display incorporating the recommended changes.

9. Conclusions and Recommendations

In general, the RAMP DSE is far superior to current tower radar displays, and can access all information required by tower controllers. The following three areas can be improved:

(a) Display Content. The content is excessive and at times redundant for control tower operations. Reducing the tag content and providing a simpler present position symbol set would make the display easier to read.

(b) Keyboard. Change to a smaller format keyboard to save valuable space.

(c) Software User Interface. The software user interface could be simplified and improved, to allow immediate access to relevant information, through its use of dedicated function keys.

Since tower operations are a combination of "heads up" (out the window) and "heads down" (radar scan), this would allow more time for "heads up" as opposed to time spent working the keyboard.

Based on this study and current RAMP DSE installation plans, a three phase approach (i.e., short-, medium-, and long-term) to implementing the proposed changes is recommended.

SOMMAIRE

1. Généralités

Le projet RAMP.DSE vise à équiper les tours de contrôle de matériel d'affichage radar numérique. La recherche lancée dans le cadre de ce projet a eu pour objectif premier de déterminer la quantité d'information devant être affichée et ensuite la meilleure manière de la présenter.

2. Analyse des tâches et des besoins en matière d'information

Dans le but d'analyser les tâches et de déterminer la quantité d'information devant être affichée, les chercheurs ont visité quatre tours de contrôle dirigeant des trafics aériens de densité et de complexité variées et ont examiné les nombreuses sources d'information disponibles. Quant aux tâches à analyser, l'information correspondante a été obtenue des documents décrivant les fonctions attribuées aux tours de contrôle et celles exercées par les contrôleurs du trafic aérien, des MANOPS et des manuels de formation.

3. Analyse des fonctions exercées par les contrôleurs

Les visites des tours de contrôle du trafic aérien et l'examen des documents pertinents ont permis de dresser la liste des fonctions exercées par les contrôleurs aériens et de les regrouper dans les quatre catégories suivantes :

(a) Contrôle du trafic aérien

- Maintenir la séparation des aéronefs,
- Coordonner les mouvements des aéronefs,
- Planifier les mouvements des aéronefs.

(b) Équipement

- Faire fonctionner l'équipement.

(c) Autres activités

- Transmettre l'information,
- Aider à la navigation aérienne,
- Transmettre l'information météo.

(d) Situations exceptionnelles

- Lancer l'alerte,
- Réagir aux situations exceptionnelles,
- Réagir aux situations dangereuses.

4. Analyse des informations devant être fournies aux contrôleurs

L'examen des documents pertinents et les interviews auprès des contrôleurs aériens un peu partout au Canada ont montré que les informations dont les contrôleurs ont besoin dans l'exercice de leurs fonctions sont relativement simples. En effet, à l'égard de chaque cible se trouvant dans l'espace aérien qu'ils contrôlent, ils doivent connaître ce qui suit :

- Sa position (par rapport à certains repères géographiques),
- Son altitude,
- Sa vitesse,
- Sa catégorie de poids,
- Son identité (indicatif).

D'autres informations telle que la vitesse verticale peuvent être à l'occasion utiles. Le système RAMP.DSE peut fournir toutes ces informations.

Étant donné que, dans des situations de trafic aérien dense, les blocs de données même simplifiés risquent d'empiéter les uns sur les autres (surtout à l'approche des pistes) et qu'il est inconcevable que les contrôleurs soient astreints à garder longtemps une attitude tête basse pour interpréter des données parfois complexes affichées sur l'écran, il s'ensuit que la condition sine qua non est de n'afficher que les informations strictement nécessaires, les autres pouvant être appelées au besoin en quantité limitée.

Autre condition, le temps consacré à la manipulation de l'équipement d'affichage doit être le plus court possible. De même, l'information affichée par le système RAMP, et les fonctions qu'il autorise, doivent être taillées aux besoins des tours de contrôle de manière à leur faciliter l'exploitation et l'interprétation des données. Le système RAMP devrait servir de simple source d'information, dont la manipulation devrait être aussi simple que possible.

5. Exploitation de l'équipement

Le réglage de la luminance semble convenir à la gamme des conditions ambiantes d'éclairage, depuis les conditions de plein jour à celles de nuit.

Le clavier est trop gros et compliqué. Un clavier ou bloc de commande moins gros et moins compliqué conviendrait davantage du point de vue de l'encombrement, du temps mis à obtenir une information et du temps consacré à la formation. Le besoin d'interroger le système se fait souvent sentir au moment où le contrôleur doit faire face à un trafic dense, et fonctionner dans une attitude de tête basse à ce moment précis peut être dangereux.

Les fonctions qui jusqu'ici étaient réglées au moyen d'une commande analogique, le réglage de la luminance, par exemple, le sont désormais par un moyen numérique : le clavier. Accéder à une fonction en passant par les diverses étapes d'un menu est une opération non seulement laborieuse, mais dangereuse puisqu'elle exige une attitude tête basse.

6. Analyse des fonctions

Nombre des fonctions permises par le système RAMP sont inutiles aux yeux des contrôleurs aériens. L'information fournie par ce système ainsi que les fonctions qu'il autorise ont été analysées et groupées selon qu'il s'agit de fonctions qui, à notre avis, doivent être éliminées, qui ne doivent servir que durant la mise en place du système et qui sont indispensables.

7. Nature de l'information affichée

Les blocs de données et les symboles de la position instantanée affichés par le système RAMP sont surchargés. Les 22 symboles différents de position instantanée affichés par le système RAMP sont difficiles à distinguer, à moins d'avoir la taille normale de 6,3 mm. Pour les besoins du contrôle aérien, il ne faut en retenir que cinq : trois symboles géométriques faciles à reconnaître représentant les catégories de poids, le symbole (*) pour les cibles non identifiées et le point d'interrogation (?) pour les cibles qui semblent avoir disparu de l'écran. Pour distinguer entre les signaux émanant des radars PSR et SSR, les symboles géométriques seront soit laissés vides, soit remplis.

Les blocs de données ainsi surchargés ne font qu'augmenter les échos parasites. Pour les besoins du contrôle aérien, un bloc ne devrait afficher que l'indicatif de l'aéronef, son altitude et sa vitesse au sol. Un autre bloc pourra être appelé au besoin, donnant, en plus de l'indicatif, la vitesse verticale, le type d'aéronef et d'autres informations particulières. Pour ce qui est du trafic en vol à vue (sans plan de vol) traversant la zone contrôlée, une fonction d'étiquetage ponctuel devra être prévue, permettant à la tour de contrôle de l'avoir affiché sur son écran au moyen des symboles d'indicatif et de position instantanée.

8. Émulation du système d'affichage RAMP

Dans le but d'évaluer quelques-unes des modifications suggérées aux blocs de données et aux symboles de position instantanée, les chercheurs ont émulé le système d'affichage utilisé par la tour de contrôle de Dorval, qu'ils ont ensuite comparé au système d'affichage incorporant les modifications proposées.

9. Conclusions et recommandations

De façon générale, le système d'affichage RAMP est très supérieur à ceux qui équipent couramment les tours de contrôle, étant donné qu'il permet d'afficher toutes les informations requises par les contrôleurs. Trois possibilités d'amélioration se présentent, pourtant, ce sont:

(a) Contenu des blocs de données. En plus d'être trop volumineux, le contenu est parfois redondant pour les besoins du contrôle de la circulation aérienne. Pour rendre ce contenu plus facile à interpréter, il suffit de le rendre plus succinct et de simplifier le groupe de symboles représentant la position instantanée.

(b) Clavier. Adopter un format moins encombrant.

(c) Interface homme-machine. Simplifier l'interface et prévoir des commandes dédiées donnant un accès direct à l'information voulue.

Étant donné que, par leurs fonctions, les contrôleurs passent constamment d'une attitude tête haute (voir ce qui se passe à l'extérieur) à une tête basse (voir ce que l'écran affiche) et vice versa, simplifier le clavier du système RAMP et le rendre moins encombrant déboucherait sur un système que les contrôleurs pourront utiliser dans une attitude plus souvent tête haute que tête basse.

A partir des résultats de la présente étude et des idées en cours concernant l'installation des équipements d'affichage RAMP, un plan de mise en oeuvre est proposé, prévu pour se dérouler en trois temps : court terme, moyen terme et long terme.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACID	aircraft identification (call sign)
ASDE	airfield surface detection equipment
ATC	air traffic control
ATS	air traffic services
CA/MSAW	collision alert/minimum safe altitude warning
DSE	display site equipment
EL	electroluminescent
GFI	government-furnished information
IFR	instrument flight rules
MANOPS	manual of operations
PC	personal computer
PED	positional entry device
PPS	present position symbol
PSR	primary surveillance radar
RAMP	Radar Modernization Project
RBL	range/bearing line
SSR	secondary surveillance radar
SVFR	special visual flight rules
VFR	visual flight rules
VTA	visual terminal area (map)

1. INTRODUCTION

1.1 Background

In the air traffic control (ATC) environment, controllers are required to monitor radar displays, identify aircraft, and communicate with pilots or other controllers to coordinate and separate traffic. The Radar Modernization Project (RAMP) is one portion of the expansion and modernization of the Canadian ATC system. One of the objectives of RAMP is to provide new display site equipment (DSE) at airport towers to enhance the data available to tower controllers. The DSE will provide tower controllers with a new digitized radar display that includes information such as aircraft position, identity, altitude, and speed information. CAE has been contracted by Transport Canada to examine the new DSE and provide recommendations that will enhance its utility in the tower environment. The primary objective of the project is to determine what information is required by tower controllers and how to best present that information.

1.2 Approach

In order to determine what information is required by tower controllers in performing their duties, a two-phase study was commissioned. In the first phase (information requirements phase), an analysis of airport tower controller activities and the type of information associated with these activities was undertaken. To perform the analysis, several airport control towers were visited so that the tower control activities could be studied. In the second phase, the operation of RAMP DSE hardware was compared to the tower controller information requirements. This report reviews the towers visited, summarizes tower control operations, provides a task analysis of tower activities and information requirements with respect to RAMP radar DSE, and gives recommendations based on these requirements.

2. TOWER VISIT SUMMARY

2.1 Airport Towers Visited

Four airport control towers were selected for the study on the basis of their traffic density and geographical characteristics. The towers and selection criteria were:

(a) Regina tower (traffic density - light)

(b) Dorval tower (traffic density - moderate)

(c) Toronto tower (traffic density - heavy)

(d) Vancouver tower (traffic density - heavy and complex).

The dates for each airport tower visit and points of contact are listed below:

- Regina tower - Visited 7-9 May, 1990
  - Contact: Mr. G. Schwartz
  - CAE: D. Runnings
- Dorval tower - Visited 9-11 April, 1990
  - Contact: Mr. A. Jacques
  - CAE: R. Kruk, D. Runnings, M. Hanner
- Toronto tower - Visited 11-13 June 1990
  - Contact: Mr. Clare Vasey
  - CAE: D. Runnings
- Vancouver tower - Visited 22-24 May, 1990
  - Contact: Mr. B. McDonald
  - CAE: R. Kruk, D. Runnings

Each tower was visited over a three-day period. The first day was allocated to familiarization with the particular airport tower layout, equipment and operations. The day was completed by observing operations during the afternoon peak traffic period. On the second day, afternoon, evening and night operations were observed. For the final day, operations during the morning peak traffic period were observed and the visit finished with a debrief in the afternoon.

3. TASK AND INFORMATION ANALYSIS

3.1 Relevant Documentation

In order to perform the task analysis and determine RAMP information requirements for tower operations, many information sources were reviewed. In addition, the airport towers listed in the previous section were visited and task-related information was extracted from tower controller job descriptions, manual of operations (MANOPS), training manuals, and tower-related task analysis information. The documentation reviewed is listed below:

(a) ATC MANOPS Part 3 Airport Control (TP 703E)

(b) ATS Administration and Management Manual (TP 704E)

(c) ATS Control Tower Site and Design Standards (TP 210)

(d) ATS Basic Controller Training (TP 1926 E)

(e) ATS Qualification Controller Training (TP 1946E)

(f) Dorval Tower Qualification Training

(g) Human-Factors of Consoles For Air Traffic Control

(h) Task Analysis Dorval Tower

(i) Task Analysis Regina Tower

(j) Task Analysis Vancouver Tower

(k) Task Analysis Toronto Tower

(l) Dorval VTA

(m) Vancouver VTA

(n) Toronto VTA

(o) RAMP Radar Data Processing System User Interface Document for the RAMP Indicator Module Operational Display (G169451 E).

3.2 Tower Controller Task Analysis

The controller training documentation was reviewed and the generic tower controller task analysis was used to select RAMP-related tower control activities. The generic task analysis is presented in figure 3-1. After reviewing the documentation and completing visits to the airport control towers,

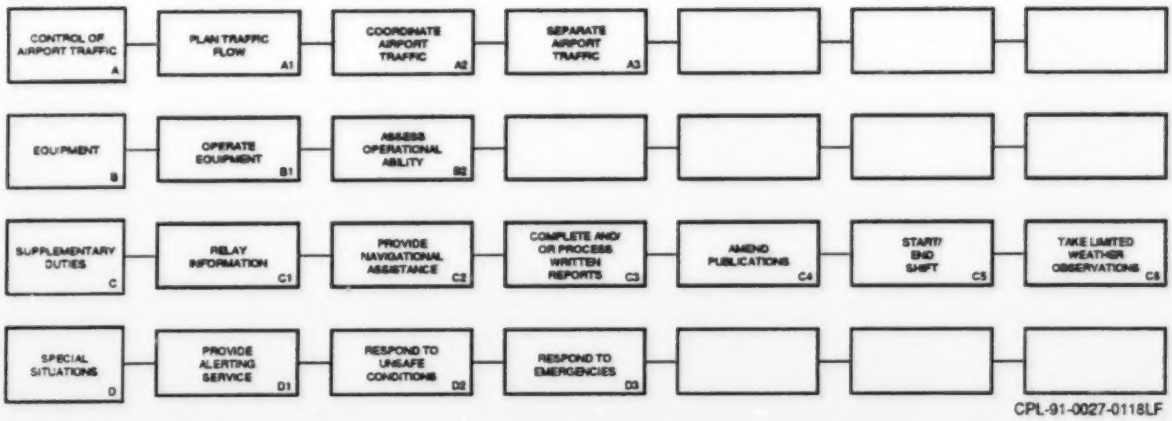


Figure 3-1 Generic Tower Task Analysis

the RAMP related activities for the tower controller were listed. These activities can be divided into four categories as follows:

(a) Control of airport traffic

  (1) Maintain traffic separation

  (2) Coordinate traffic flow

  (3) Plan traffic flow.

(b) Equipment activities

  (1) Operate equipment.

(c) Supplementary activities

  (1) Relay information

  (2) Provide navigational assistance

  (3) Weather observations.

(d) Special situations

  (1) Provide alerts

  (2) Emergency response

  (3) Respond to unsafe conditions.

A detailed breakdown of the activities in each of these categories is provided.

3.2.1 Control of Airport Traffic

Tower control staff serve the MANOPS objective for aircraft control service, which is to maintain the safe, orderly, and expeditious movement of aircraft operating in Class C airspace by:

(a) Locating and identifying aircraft in the light, medium and heavy weight categories, some of which may be subject to special visual flight rules (SVFR).

(b) Issuing instructions, clearances, authorizations and information to pilots in order to maintain aircraft separation.

(c) Ensuring separation between aircraft utilizing unique operating characteristics, i.e. high performance fighter aircraft, helicopters in the light- and medium-weight categories and conventional aircraft.

(d) Applying time or radar minima to ensure wake turbulence separation to aircraft using same or crossing runways and when flight paths converge.

(e) Determining runway use and approach facility, taking into consideration meteorological conditions, noise abatement procedures, wake turbulence separation, and aircraft operating characteristics.

(f) Coordinating and exchanging information with the appropriate instrument flight rules (IFR) unit for the transfer of control and exchange of information on arriving and departing aircraft.

(g) Coordinating the control of aircraft with other ATC units.

(h) Deciding upon corrective action as situations are identified through the assessment of traffic and airport activities.

Relevant subactivities in maintaining separation of airport traffic include:

(i) Issue Clearances.

- Takeoff
- Landing
- Overflights.

(j) Issue instructions.

- Routing
- Alternate
- Holding
- Overshoot
- Sequencing
- Restrictions
- Turns
- Altitude assignment
- Speed control.

(k) Issue traffic information.

- Restrict traffic flow
- Apply wake turbulence minima
- Approve simulated approaches
- Apply SVFR procedures.

Relevant subactivities in planning and coordinating traffic flow include:

(l) Establish position of airborne traffic.

(m) Coordinate control of airspace.

(n) Determine impact of weather on operations.

(o) Determine approach(es) in use.

(p) Plan IFR arrivals/departures.

(q) Plan visual flight rules (VFR) arrival/departure routes.

(r) Plan overflight routes.

(s) Coordinate control transfers.

(t) Give and obtain handoffs.

(u) Plan off-airport operations.

(v) Coordinate special flights.

(w) Restrict traffic flow.

(x) Plan simulated approaches.

(y) Plan flight check operations.

(z) Prepare flight progress strips.

(aa) Plan SVFR operations.

3.2.2 Equipment Activities

The operation of equipment and assessment of operational equipment fall under the heading of equipment activities. A breakdown of further subactivities and duties for the operation and assessment of equipment is not relevant for the RAMP DSE. There are, however, several RAMP DSE (equipment) related factors such as user friendliness that are relevant.

3.2.3 Supplementary Activities

Supplementary tasks which could be supported by digitized radar data include assessment of limited weather observation with the weather data feature of the RAMP and provision for navigational assistance with:

(a) Radar vectors.

(b) Route information.

(c) Geographical information.

(d) Transfer to other ATC units.

(e) Instrument approach profiles.

3.2.4 Special Situations

Response to special situations is categorized as response to conditions or events which could affect safety. Digitized radar data could aid controllers in analyzing, acting and advising in unsafe conditions pertaining to:

(a) Bird activity.

(b) Turbulence.

(c) Loss of communication.

Digitized radar data can also be of assistance in emergency conditions pertaining to:

(d) Hijackings.

(e) Lost aircraft.

(f) VFR aircraft in IFR conditions.

(g) Crash on/off airport.

3.3 Information Flow and Typical Activities

Positions within the control tower are arranged to provide the appropriate sight lines for both the ground and airport controller and to optimize the flow of information. In general, the flow of information (i.e., flight strips) for departures is:

Clearance delivery -> ground control -> airport control

The order is reversed for flight arrivals except that clearance delivery is not required. For arrivals, the flow of information is:

Airport control -> ground control -> apron control

Based on the information flow, the airport control position is the focal point for both departing and arriving flights. The fact that proper sight lines must be provided implies that the position is in fact a very heavy "heads up" or "head out the window" position. This is confirmed by the tower task analysis described previously and through interviews with tower controllers. Since the RAMP DSE is intended to be the primary aid to the airport control position (with secondary functions for ground and perhaps clearance delivery), the display must be optimized to allow the "heads up" activities to continue undisturbed. These activities include checking and issuing runway clearances, takeoff clearances, and abnormal conditions such as bird activities and emergency situations. The use of radar data is normally limited to a brief visual scan for coordinating traffic flow and maintaining separation. Therefore, the introduction of RAMP DSE hardware should be unobtrusive and enhance the normal tower controller activities.

3.4 Tower Control Information Requirements Analysis

3.4.1 Information Type and Classification

Based on the review of documentation and discussions with tower staff across Canada, the display needs for control of airport traffic are relatively straightforward. For each target affecting their airspace, tower controllers want to know:

- Position (with sufficient geographic information)
- Altitude
- Speed
- Weight class
- Identification (call sign).

Additional information such as vertical velocity, secondary surveillance radar (SSR), primary surveillance radar (PSR) may be useful from time to time. The RAMP DSE has the ability to provide all this data, plus much more; we did not identify any target related data desirable to tower controllers which is not available in the RAMP DSE. Following through with each task category and subtask described in the preceding section, an assignment of information source and type can be made from one of the information sources; namely, who (aircraft identification), where (location), altitude, speed, and weight classification.

Information available from RAMP is categorized into one of four types:

(a) Basic target data (primary information).

- Includes PPS, basic tags (altitude, identification, speed) and minimum geographic data (outline or overlay map)

NOTE: This should be on the display at all times.

(b) Available supplementary data (secondary information).

- Includes alternate tag data, more detailed geographic data, bezel, range rings

NOTE: This should be available to the controller via the keyboard.

(c) Warning data (critical information).

- Such as emergency transponder transmissions

NOTE: This comes up automatically.

(d) Superfluous information.

- Includes redundant tag information and present position symbol (PPS) symbols, supplementary data of minimal use to tower controllers

NOTE: This should be deleted during RAMP DSE setup.

The information requirements and type of information for each RAMP related activity as identified in the task analysis is presented in table 3-1. The information required for each task is classified as either critical, primary, secondary, or superfluous as described above and within each type, the information source required for the task is identified numerically.

Table 3-1 Information Source and Classification

		Crit	Prim	Sec
(1)	Control of airport traffic			
	- Maintain traffic separation		x	x
	- Coordinate traffic flow		x	x
	- Plan traffic flow		x	x
(2)	Equipment activities			
	- Operate equipment		x	
	- Assess operational equipment		x	
(3)	Supplementary activities			
	- Relay information		x	
	- Provide navigational assistance		x	x
	- Weather observations			x
(4)	Special situations			
	- Provide alerts	x		
	- Emergency response	x		
	- Respond to unsafe conditions	x		

NOTE: For information type, the following sources are included.

Critical: Position, altitude, identification, speed, weight class, emergency transmissions and codes
Primary: Position, altitude, identification, speed, and weight class
Secondary: Alternative data fields, heading, additional geographic data, map overlays.

On the basis of observations, documentation, and interviews, we have concluded that the information provided by the current RAMP DSE needs no additions. In fact, the problems with information from the RAMP DSE are, rather, in the opposite direction: A substantial proportion of the data and functions in this display are superfluous in the tower environment. Since even relatively simple target tags may overlap in high traffic density situations (especially near the runways), and since tower controllers cannot spend significant periods of time "heads down" on the display to interpret complex data, it is our observation that the baseline condition should be the display of the minimum necessary information (e.g., a PPS coded for weight class and a tag with identification, altitude, and ground speed). A limited set of additional data could be brought up on demand (e.g., an alternative data field function key). However, the time spent operating the display should be kept to a minimum and as much of the available data is of low value to tower controllers, even alternative data should be constrained. In order to achieve a simple and effective interface, the information and functions available will need to be filtered to reduce complexity of operation and display interpretation. This will improve the utility of the RAMP DSE in the tower environment.

It is our opinion that for the tower controller per se, the RAMP DSE should be strictly an information source and that manual interaction with the system be kept to a minimum. If there is any intention to use the RAMP DSE as a device for handoffs, or flight plan entry and amendments, then those functions should be served by dedicated tower staff other than the air controller(s). The one position currently in the tower that may be able to handle these functions is clearance delivery. Passing these functions onto clearance delivery, however, changes the standard flow of information and could potentially be very confusing. One feasible alternative would be to add another position to fulfill this new role. Staff fulfilling this function should be, at a minimum, fully trained in typing (as keyboard entry time must be kept to a minimum), as well as the operation of the RAMP DSE in its full complexity. The training load associated with these conditions may require that the positions be dedicated, thereby reducing scope for rotation of positions in the tower during a normal shift. As ATC staffing is limited and space available in towers is very constrained this option does not strike us as an efficient way to proceed. In our opinion, any introduction of full function application of the RAMP system in towers should be preceded by a full tower system task analysis, as the roles of existing staff would have to be redefined.

4. RAMP FUNCTION ANALYSIS AND ALLOCATION

4.1 Equipment Operation

Equipment operation is one of the four categories of tower controller activities identified in government-furnished information (GFI) task analyses. A number of RAMP functions are superfluous to the tower control task. Several display control functions normally served by analog controls (such as display brightness) must be accessed through the keyboard. In consequence, the keyboard is excessively large and complex. The complexity of operation of the RAMP DSE may also have a significant impact upon the effectiveness of the display. More specifically, all operations with the display are performed through the use of the keyboard by either direct access, or in many cases, through the use of a menu system. Sequencing through several levels of a menu to access and evaluate the effect of the function, only to decide the level chosen was incorrect, is extremely time consuming and primarily a "heads down" activity. When the traffic density is low, this may not be a serious problem. In many cases, however, the requirement for accessing a function occurs when the controller is busy and traffic density is high. Operating in a "heads down" mode during this period could potentially compromise tower operations.

In most control towers, free or uncluttered working space is at a premium. The standard RAMP DSE keyboard is 21.375 inches long by 9.0 inches wide by 2.75 inches high and weighs 7.0 pounds. Introducing the keyboard will severely limit any remaining counter space and in some towers may restrict the flow of strip information (see figure 4-1). Towers such as Vancouver that receive a steady flow of VFR aircraft passing through the zone maintain a record of the aircraft position by quickly producing a strip (average time to produce the strip is approximately 10 seconds). The same activity using the RAMP keyboard to enter or correlate a flight plan would take much longer (minutes) to complete at which time the aircraft would likely be out of the zone. A quick tag function (affecting local displays only) may be a useful addition here.

It is our assessment that use of the RAMP DSE keyboard can be extremely complex for many functions and its operation (and training to operate) is excessively time consuming and awkward in the tower environment. An alternative keyboard or control unit that is reduced in size and simplified in function would greatly help with space restrictions, time to access functions and training. One potential implementation could be a programmable touch sensitive LED display which contains function specific keys for most operations, but could be changed to a QWERTY keyboard by pressing a keyboard function key. A small display field on the control unit would allow feedback on keyboard entry. A control unit of this type displaying soft function keys is shown in figure 4-2, and the selectable QWERTY keyboard display is shown in figure 4-3.

As introduction of RAMP DSE equipment into towers is already underway, replacement of hardware is not a viable solution in the short term. An interim solution might be to separate available RAMP DSE features into the following categories and make easily available to controllers only those in the first category:

(a) Those required by airport controllers

(b) Those required only during system setup

(c) Those not required.

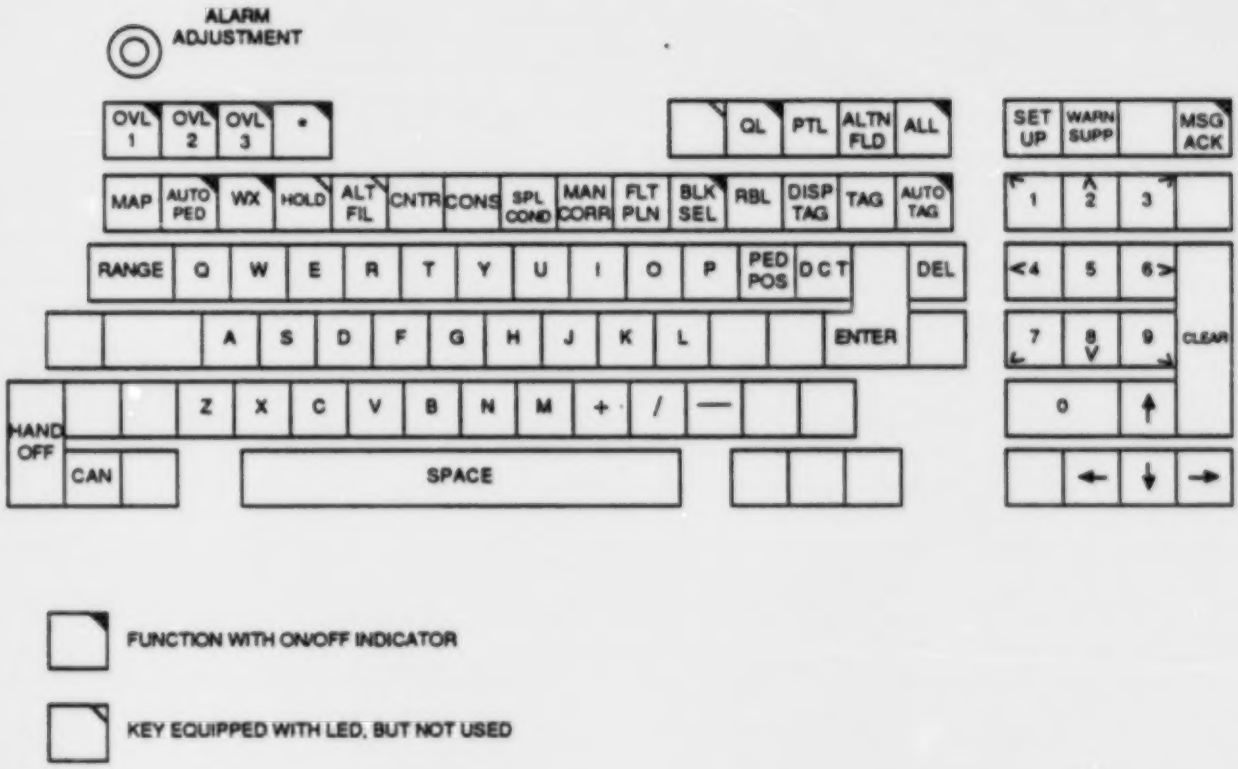


Figure 4-1 Standard RAMP DSE Keyboard

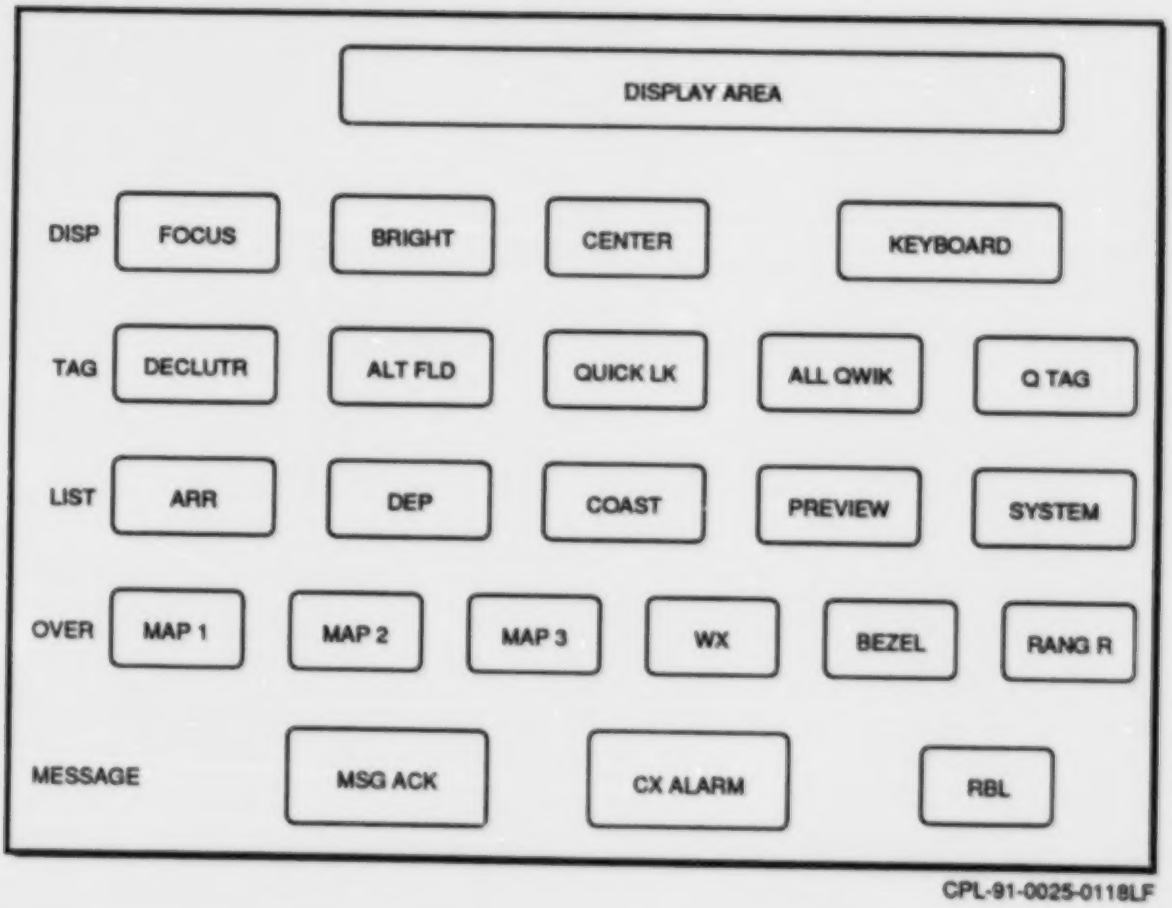
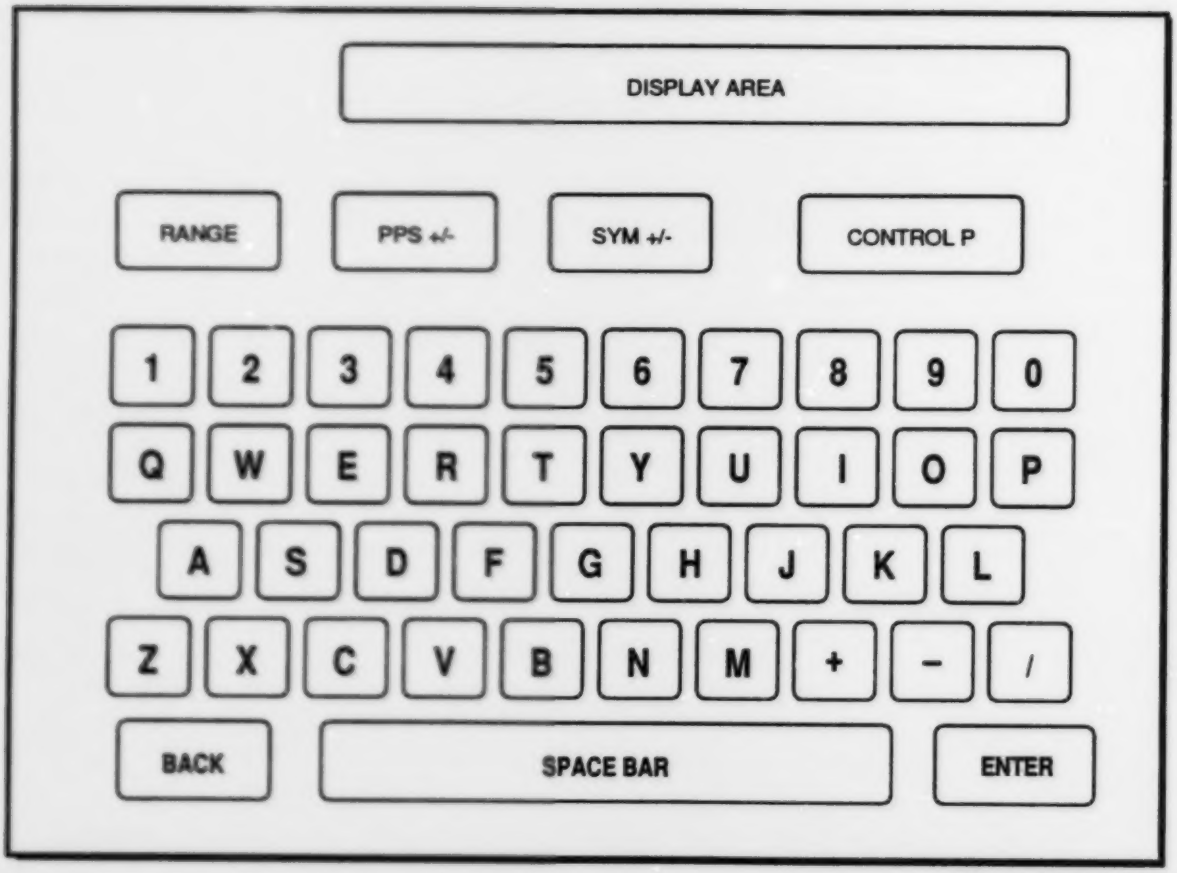


Figure 4-2 Alternative Tower Keypad



CPL-91-0026-0118LF

Figure 4-3 Alternative Tower QWERTY Keypad

This approach would also serve as a field trial for validating which functions are really useful to controllers. The following analysis of functions breaks down available RAMP DSE features in this way, but note that the solution guidelines are toward the long term and recommended implementation is based upon the use of a simplified control unit such as that shown in figure 4-2 and figure 4-3.

4.2 Analysis of Functions

In analyzing the utility of the RAMP DSE in the tower environment, we are concerned primarily with the function of a digitized radar display in monitoring air traffic. Additional capabilities of the display, such as provision of geographical or weather information, are categorized as useful to the extent that they support the control of airport traffic. There are cases where information provided by the RAMP DSE may also support supplementary activity such as provision of navigational assistance or weather data to aircraft. However, care must be taken to ensure that provision of information to support supplementary activities does not interfere with the primary traffic control function by cluttering the display or overloading the controller with extraneous data. In tower control zones where traffic is less dense, or aid to VFR aircraft is a substantial proportion of the tower controller's workload (e.g., Regina), higher priority may be assigned to support of supplementary functions, and perhaps it may be appropriate to do so. However, the general goal in all cases should be to provide no more information than is necessary to fulfill the task at hand. To accommodate this goal, the data and functions available in RAMP have been analyzed in table 4-1 and broken down into functions which (in our opinion) should be deleted, functions to be used during system setup, and functions that would be used regularly by tower controllers. The functions that will be used are also broken down by recommended availability. Definitions for availability are as follows:

(a) Always. Functions recommended as always should be available to the tower controller at all times with minimum requirements for keyboard interaction (according to function priority). Functions which are regularly used should be assigned dedicated function keys (FK in the tables) and one keypress should activate them (Note 1). Functions which are useful but rarely used should be accessible through the keyboard (K in the tables). Display brightness and focus should be adjustable via analog means (Note 2).

(b) System Setup. Functions recommended as available for system setup should be available through the keyboard for initial setup. The values of these functions should remain fixed thereafter.

(c) Delete. Functions recommended to be deleted have been evaluated to be extraneous or inappropriate in the tower environment.

NOTE 1: The controller may wish to see supplementary data (e.g., bezel) for a short period of time or for extended periods. To serve this requirement, the information would be displayed after its function key is depressed and displayed until the key is pressed a second time to remove the information.

NOTE 2: Use of the positional entry device (PED) to increase/decrease focus or brightness may be the simplest implementation in the short term.

Table 4-1 RAMP Function Analysis

FUNCTION	RECOMMENDED AVAILABILITY	CURRENT IMPLEMENTATION	RECOMMENDED IMPLEMENTATION
Display setup			
Intensity	Always	FK -> K	FK + PED
Altitude filter	System setup	FK -> K	K
Altitude filter deselect	Delete	-	-
Tabular list reposition	System setup	FK -> K -> PED	FK + PED (Note 1)
Data tag field select	System setup	FK -> K	K
Data class bright	System setup	FK -> K	K
Set PED home	System setup	FK -> PED	K + PED (Note 2)
Handoff warning	Delete	-	(Note 3)
Leader line length	System setup	FK -> K	K
Range ring select	Always	FK -> K	FK
Bezel select	Always	FK -> K	FK
Alphanumeric character size	Always	FK -> K	K
Symbol size	Always	FK -> K	K
Background pattern	Always	FK -> K	K
Display focus	Always	FK -> K	FK + PED
Maintenance display subfunction	Delete	-	-
Data tag presentation			
Predicted track line	Delete	-	-
Data tag select	Delete	-	-
Quick look all	Always	FK	FK
Select quick look	Always	FK -> K	FK,PED
Alternate field disp	Always	FK	FK
Auto tag	Delete	-	FK + PED (Note 4)
Manual data tag	System setup	FK -> K	K
Splat	Delete	-	-
Block select	Delete	-	-
Warning supp	System setup	FK -> K	K (Note 5)
PED control			
Stiff stick	Always	PED	PED
Auto PED	Delete	-	-
PED home	Delete	-	-
Position consolidate	Delete	-	-
Acknowledgment			
Message	Always	FK	FK
Special condition	Always	FK	FK
Cancel audible alarm	Always	FK	FK
Other display control			
Display off center	Always	FK -> PED	FK + PED
Display default center	Delete	-	-
Display range select	Always	FK -> K	K
Map select	System setup	FK -> K	K (Note 7)
Map overlays	Always	FK -> K	FK
Range/bearing line function	Always	FK -> K	FK + PED (Note 6)
Weather select	Always	FK -> K	FK
Weather history	Delete	-	-
Flight plan function	Delete all functions except quick tag (Note 3)		

NOTE 1: Lists and menu should have cursor hook points which would allow them to be shifted by moving the cursor to the hook and pulling the whole list to the new position (list function key depressed).

NOTE 2: PED home position should be fixed at system setup. PED cursor should be home whenever capture function has been entered (i.e., cursor is released).
NB: Cursor should not flash.

NOTE 3: Tower controllers do not have the time to enter flight plans into RAMP and/or use the keyboard for handoffs as this would require significant "head down" time and may compromise safety.

NOTE 4: It is our observation that automated tag functions do not completely declutter the displays and at times cause the controller to temporarily lose the tag. To serve the function of clearing other tags so that a specific target may be discriminated, we suggest a manual function key (declutter). When pressed while the cursor is on a target PPS, this would delete all tags except the one selected.

NOTE 5: Maneuvering aircraft in the tower control zone may require software changes to the collision alert/minimum safe altitude warning (CA/MSAW) alerts.

NOTE 6: The range/bearing line (RBL) function could be useful in aiding lost aircraft but its implementation should be significantly simplified. During initial setup the "from" position should be fixed at some airfield position (e.g., tower) and distance units should be fixed. For the controller, operation of the RBL function should be as simple as placing the cursor on a target PPS and depressing the RBL function key. The system would then display an RBL for that target.

NOTE 7: During map selection, map center offsets may be specified for towers with split jurisdiction (i.e., towers in which the control zone is split between the tower controllers).

Implementation key:

K = Keyboard
FK = Dedicated function key
PED = Position entry device (stiffstick)

In order to summarize the function allocation and analysis, three other tables have been generated. These are presented in tables 4-2, 4-3, 4-4 respectively. The first table lists the functions to be deleted and gives the reasons for deletion. The second table lists the system setup functions and their operation. The final table lists the functions which should be available and describes how they should be accessed.

Table 4-2 Summary of Functions to be Deleted

FUNCTION:	REASON:
Altitude filter deselect	Redundant with quick look.
Hold list	N/A in tower environment.
Keyswitch list	Extraneous.
Handoff warning	RAMP DSE not appropriate for tower flight plan entry.
Maintenance display function	Useful for maintenance only.
Show predicted track line	Extraneous.
Data tag select	Redundant.
Auto tag	Confusing.
Splat	All nonfiltered targets should be continuously displayed since a large proportion of targets may not be on flight plans.
Block select	Extraneous.
Auto PED	Extraneous.
PED home	Should be automatic.
Position consolidation	N/A in tower environment. Data should be shared across all displays in a tower, display control should not be shared.
Display default center	Extraneous.
Weather history	Extraneous.
Flight plan and flight control	Inappropriate for tower controller.

Table 4-3 Summary of System Setup Functions

FUNCTION:	OPERATION:
Altitude filter	Should be site specific and consistent.
Tabular list reposition	List and menu position should be selected at setup and remain consistent (e.g., arrival list).
Data tag field select	Data tag contents for normal and alternate fields should be selected at setup and remain consistent.
Data class brightness	Relative brightness of tags should be set at setup and remain fixed.
Set PED home	PED home position should be selected at setup and remain constant.
Leader line length	Should remain fixed after setup.
Manual data tag positions	Data tag positions (relative to PPS) should be site specific and arranged for minimal overlap according to sector, arrival, departure or runway in use at system setup. Variations in location in accordance with traffic conditions may be implemented to reduce clutter but would lose the attribute of consistency.
Warning suppression	Area suppression for ground clearance and collision alert may be required as aircraft maneuvering in a tower control zone will often display conflicting tracks and/or descent to ground level.
Geographic map select	The geographic map for a tower control zone and surrounding area should be selected at system setup.
RBL setup	Should be site specific for "from" geographic position and units.

Table 4-4 Summary of Functions Available to the Tower Controller

FUNCTION:	OPERATION:
Display intensity	Tower light conditions change regularly and should be compensated for with a manual access through (analog) brightness control as up to eight keyboard operations is awkward. Selection of a background pattern could be made available through the keyboard but may increase focus and clutter problems.
Display focus	It may be necessary to adjust focus with changes in brightness. As such, keyboard access is awkward.
List selection	Access to specific lists as well as the menu should be quickly available by depressing a dedicated function key (a cursor hook should be displayed to allow PED position of lists).
Range ring select	Range rings should be available via a single function key.
Bezel select	Same as range ring select.
Alphanumeric character size	Lower priority via keyboard access.
Symbol size select	Lower priority via keyboard access.
Quick look all	Should be available with a single dedicated function key.
Selective quick look	It should be possible to quick look at specific targets with a dedicated function key and the PED cursor.
Alternate field display	An alternate (but still limited) set of data fields should be displayed via a dedicated function key. Actual content may be site specific and designated at system setup.
Cursor control (PED)	Some type of cursor control (joystick, stiffstick, trackball) should be available to the controller.
Acknowledgement	It should be possible to acknowledge messages or special conditions with single function keys. A separate dedicated key is required to cancel alarms.

Display off center	It may be useful to move the center of the display, but at reduced priority, with the keyboard and PED control.
Geographic map overlay	Available via dedicated function keys.
Weather overlay	Available via dedicated function keys.
Range/bearing line (RBL)	Dedicated key with cursor to obtain target RBL.
Quicktag (New function: Not currently available)	For transiting aircraft which show as targets on the DSE but have no tag, for the tower only.
Display range selection	Lower priority via keyboard access.

NOTE: An example of a reduced size tower control unit specific to the DSE and replacing the full keyboard is shown in figure 4-2.

5. RAMP DISPLAY ISSUES

5.1 Physical Characteristics

The first step in the analysis of display issues for the RAMP DSE is to examine the physical characteristics of the display. The present section will concentrate on issues relevant to the CRT display since the keyboard has already been discussed in detail. Included in this analysis are issues such as screen size, brightness, contrast, glare, and physical size and weight.

The standard RAMP CRT is a 40.6 cm (16.0 inches) screen similar to the airfield surface detection equipment (ASDE) tower screen currently used to monitor ground movements. The bezel mounted onto the screen reduces the viewable area to a 35.5 cm (14.0 inches) circle. The entire RAMP DSE unit measures 47 cm wide by 47 cm high (18.5 x 18.5 inches) by 71.1 cm deep (28.0 inches) and weighs 43.1 kg (95.0 lbs). The size and weight make it awkward to mount the RAMP DSE in the tower. Mounting the system in a console may require console modifications while mounting overhead will require support equipment for raising and lowering. In most cases, it is probable that the RAMP DSE can be made to fit. The screen itself has an anti-glare reflective coating (again similar to ASDE) to reduce reflections and glare. Brightness adjustments are made digitally by sequencing through the menu and selecting the desired level (seven levels are provided). In addition, brightness for targets and data tags can be adjusted independently. The brightness adjustments appear to adequately cover the range of ambient lighting conditions (sunlight to nighttime operations).

5.2 Information Display and Content

With respect to information display and content, the main goal is to provide the critical and primary information required by the tower controller while making secondary information available through the use of function or quick access keys. This reduces the potential for clutter, provides a logical and standard interface, and reduces the access time for retrieval of data.

In the RAMP DSE, the information content is in excess of that required for standard tower controller activities. By having too much information displayed at once, the time to retrieve relevant information is increased. The two areas where the information content is too great are the present position symbols (PPS) and the data tags. The standard RAMP DSE PPS's are shown in figure 5-1. As can be seen, there are 22 unique symbols. The current PPS set encodes a great deal of information which is of no interest to the tower controller. Furthermore, the symbols are difficult to discriminate unless they are near their full size of 6.3 mm (which also increases clutter). During interviews, tower controllers indicated that the summary information required from the PPS for a tower controller is position, (weight class would be a useful addition). Some controllers wanted to have an indication of radar return characteristics (i.e., SSR only or SSR/PSR combined). Others were of the opinion that with a digital radar display this requirement might be unnecessary. As a significant proportion of targets in a tower control zone may not have flight plans, the uncorrelated symbol should be retained. As well, technical centre staff indicated that coasting targets should be distinct. To serve those requirements, the PPS set can be reduced to five symbols for tower controllers. For weight class (correlated), three easily distinguishable geometric symbols (triangle: light, square: medium, circle: heavy) can be employed with the splat (*) for uncorrelated and question mark (?) for coasting targets. If PSR and SSR discriminations are required, then the triangle, square, and circle can be either filled or unfilled (filled symbol: SSR/PSR combined, unfilled symbol: SSR only).

PPS SYMBOL SET

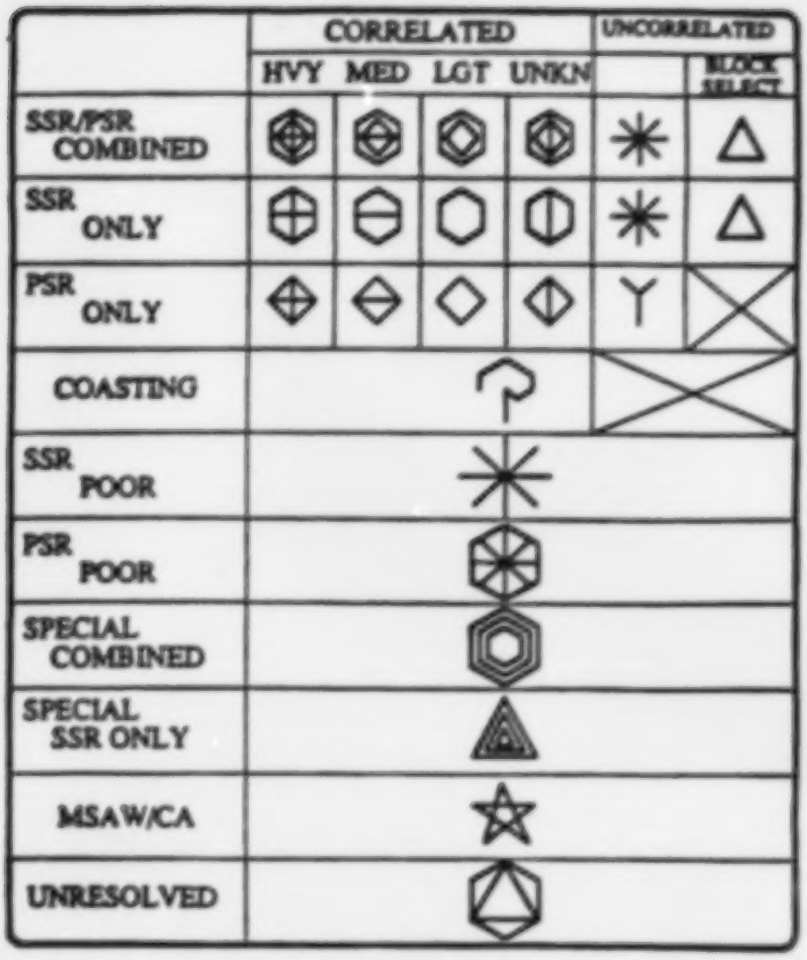


Figure 5-1 Standard RAMP DSE PPS

Current data tags contain both excessive and redundant information which increases clutter. For the tower controller, a basic tag would include ACID, altitude, and ground speed. An alternative field tag would retain ACID and could include items such as vertical velocity, aircraft type, and any special notes. For VFR traffic passing through the zone (i.e., no flight plan), a quick-tag function would allow the controller to monitor these aircraft with ACID as well as PPS on the display. The tags themselves have adequate size settings or levels to allow the controller to see the information from sitting or standing position up to approximately six feet away.

For geographical reference, a map containing the minimal amount of information to monitor traffic should always be present. Alternative secondary information that may occasionally be used, such as map overlays, bezel, and range rings, should be displayed by depressing a single function key. This will minimize the "heads down" interaction with the DSE and maximize the "heads up" time.

5.3 RAMP DSE Emulation

In order to evaluate some of the proposed changes to the PPS set and tag information, the standard RAMP DSE display for Dorval tower was emulated on a Silicon Graphics personal IRIS. The emulation was based on typical Dorval traffic patterns and included their current geographical map. Figure 5-2 presents the standard RAMP DSE display and figure 5-3 presents the proposed simplified display. Staff from Dorval tower visited CAE on October 4, 1990 to view the emulation and comments about the simplified display were positive. According to the controllers, the simplified display provided the required data, and the data was easier to discern than with the standard (current) RAMP DSE PPS and tag configuration.

Figure 5-2 Standard RAMP DSE Display

Figure 5-3 Simplified RAMP DSE Display

6. ALTERNATIVE TECHNOLOGIES

The appendix deals with alternative techologies that could replace the RAMP DSE in the tower environment. Technologies that could be used include conventional raster CRT displays which could replace the RAMP vector display, and several alternatives to the RAMP keyboard. Possible RAMP keyboard replacements include:

(a) Conventional personal computer (PC) keyboards, with or without added function keys.

(b) Compact keyboards.

(c) Programmable electroluminescent terminals (EL touch panels) with touch-screen overlays.

(d) Compact, dedicated function key panels.

(e) CRT touch screens.

Figure 6-1 shows a 48.3 cm (19.0 inch) raster CRT, a compact keyboard, an EL touch panel and a mouse PED. The appendix compares possible RAMP keyboard replacements.

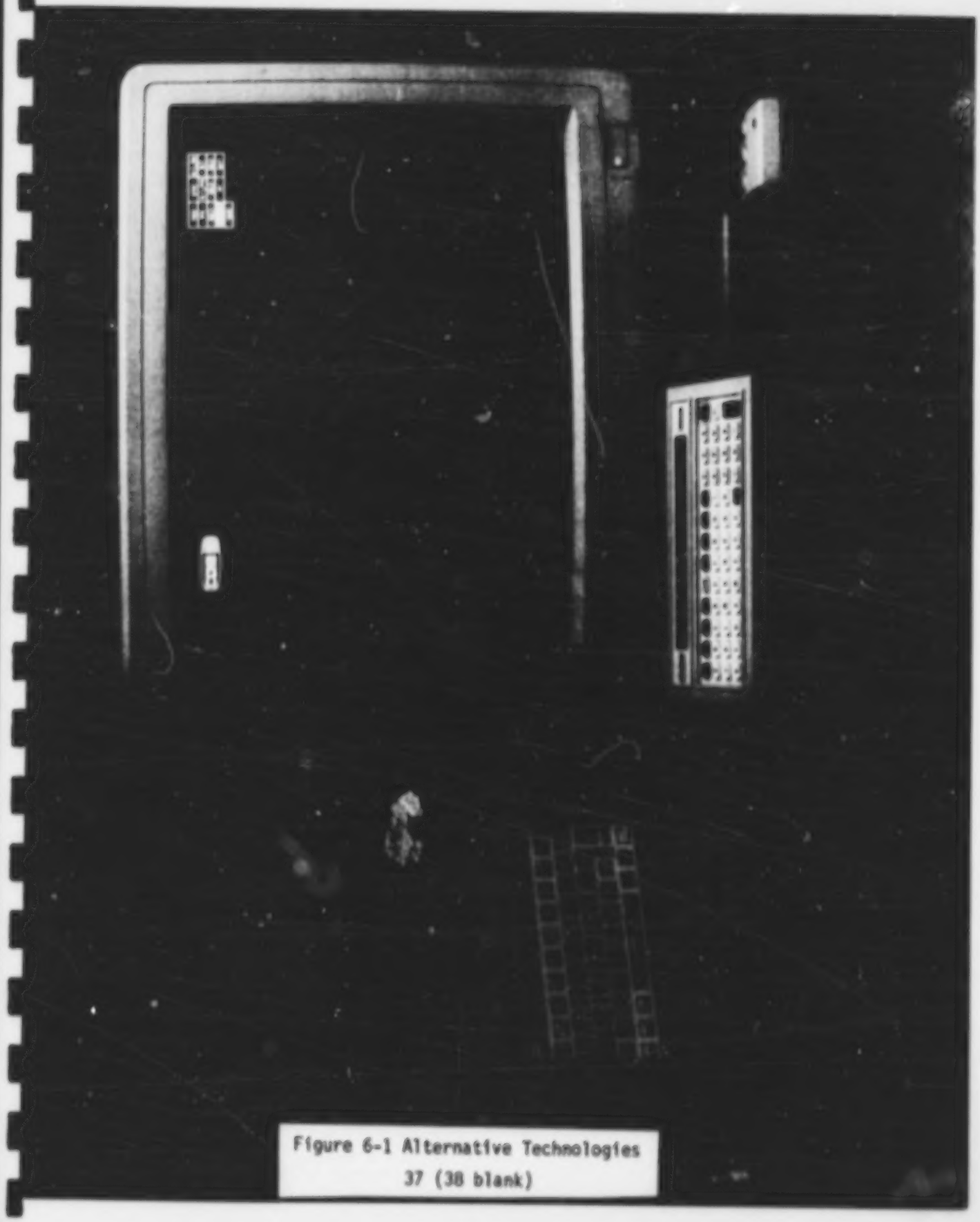


Figure 6-1 Alternative Technologies

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Tower RAMP DSE Summary

In the preceding sections, RAMP DSE operating and display characteristics were evaluated with respect to tower controller task and information requirements. In general, the RAMP DSE is far superior to current tower radar displays and can access all information required by tower controllers. The major problem with RAMP DSE is that it has not been optimized for control tower operations.

7.2 Conclusions

For the optimization of RAMP DSE in tower operations, there are three areas that can be improved; namely, display content, keyboard, and software user interface. First, the content is excessive and at times redundant for control tower operations. Reducing the tag content and providing a simpler present position symbol set (as described in paragraph 5.2) would make the display easier to read. Since tower operations are a combination of "heads up" (out the window) and "heads down" (radar scan), changing the keyboard to a simpler and smaller size would allow more time for "heads up" as opposed to time spent on working the keyboard. With a keyboard change, the software user interface could be simplified to allow immediate access to relevant information through the use of additional function keys.

Again, it should be stated clearly that the analysis of RAMP DSE hardware in the previous sections is based on tower operations and requirements. The recommendations and conclusions stated here are not necessarily applicable to other ATC operations or environments.

7.3 Recommendations

Based on the study and current RAMP DSE installation plans, a three-phase approach (i.e., short term, medium term, and long term) toward implementing the proposed changes is recommended as follows:

(a) Short Term. As RAMP DSE installations have already begun in several towers, hardware changes cannot be quickly implemented. Therefore, within the constraints of the current RAMP software, a validation trial for the report conclusions should be conducted during selected tower shifts.

  (1) Use the adaptation matrix to reduce display complexity as much as possible (e.g., map content, etc.)

  (2) Limit the functions available to the tower controller as detailed in this report.

(b) Medium Term. In the medium term, system modifications to both hardware and software can be implemented as follows:

(1) RAMP DSE keyboard should be replaced by a compact keyboard with direct access to functions as described in the report. In addition, alternative methods of adjusting brightness, contrast, and focus should be provided.

(2) Software modifications to eliminate irrelevant information, simplified PPSs, and unnecessary functions should be implemented.

(c) Long Term. In the long term, additional hardware modifications and tower controller activities should be addressed as follows:

(1) Review and redefine tower controller activities. Determine the suitability and implementation of techniques such as electronic strips and electronic hand-offs as technology matures and reliability increases.

(2) Review and assess ability of standard raster display technology and graphic workstations (e.g., Silicon Graphics' IRIS) to replace RAMP DSE.

APPENDIX

Alternatives to RAMP DSE Hardware

In the long term, it may be worthwhile to consider replacing the RAMP vector display and its keyboard with an integrated raster graphics workstation. A decision regarding adaptation of newer technology however, must be based upon the results of a full tower requirements analysis. Furthermore, while there are a number of very capable graphics workstations currently on the market, new models with improved processing and display characteristics are being introduced at a rapid rate. Any review of available technology in this area would be obsolete within a year. For the purpose of this analysis therefore, we have restricted the review to technology alternatives available off-the-shelf to replace the RAMP keyboard. Replacement of the RAMP keyboard is an option we believe should be considered in the near term. For the tower application, it is the least satisfactory component of the RAMP DSE hardware suite.

We are reviewing off-the-shelf technology rather than recommending development of a purpose-built I/O device for three reasons:

- Development of custom hardware is time consuming
- Development of custom hardware is expensive
- Development of custom hardware is unnecessary because a wide variety of flexible programmable I/O devices are available which could fulfill the requirements of a tower RAMP keyboard replacement.

There are a number of technology types which could be considered for the RAMP DSE I/O. They include:

- Conventional personal computer (PC) keyboards, with or without added function keys
- Compact keyboards
- Programmable electroluminescent terminals with touch-screen overlays
- Compact, dedicated function key panels
- CRT touch screens

All of these technologies are readily available and sufficiently well developed to be reliable. Their relative advantages and disadvantages are as follows:

(a) PC keyboards.

(1) Advantages:

- Wide variety of keyboard configurations available.

(2) Disadvantages:

- Still relatively bulky 38-53 cms x 13-18 cms (15-21 inches x 5-7 inches)

- Limited number of dedicated function keys (16 or less)

- No integrated lighting system.

NOTE: Supplementary function keyboards are available, (e.g., Mextel Autokey 20/20) but add weight and bulk.

(b) Compact keyboards.

(1) Advantages:

- Much smaller and lighter than conventional keyboards (e.g., MEI Space Saver is 27.3 x 15.2 cms (10.75 x 6.0 inches), weighing 0.95 kgs (2.1 lbs), with full keyboard)

(2) Disadvantages:

- All conventional keyboard disadvantages (except bulk) plus reduced key spacing

(c) Electroluminescent touch terminals.

(1) Advantages:

- Integrated lighting

- Programmable (can be conventional keyboard and/or dedicated function keys)

- Compact (e.g., Emerald Computers' FPS 570R is 21.6 cms x 27.9 cms (8.5 inches x 11.0 inches) weighing 2.95 kgs (6.5 lbs)).

(2) Disadvantages:

- No tactile feedback for keypresses.

(d) Dedicated function key panels.

(1) Advantages:

- Very compact (e.g., Panel-Tec IPM 1224 m 8.9 cms x 21.8 cms (3.5 inches x 8.6 inches) weighing 0.63 kgs (1.4 lbs))

- Tactile feedback.

(2) Disadvantages:

- No QWERTY keyboard

- No PED

- No inherent lighting.

(e) CRT face touch screen.

(1) Advantages:

- Could eliminate need for separate key panel.

(2) Disadvantages:

- Touch menus use limited available display space (clutter)
- Touch overlays reduce screen luminance 10 to 30%
- No tactile feedback
- Operator must be at CRT face to use the device.

Summary of Alternatives to the RAMP Keyboard

In our view, dedicated function key panels are not truly viable alternatives to the current RAMP keyboard because of severely limited flexibility (especially lack of QWERTY keyboard). CRT touch screens are not suitable because they use display space, which runs counter to the desire to reduce clutter. The suitability of a conventional or compact PC keyboard depends upon the results of in-service evaluation of the current tower RAMP and the extent to which the recommendations of this report are proven to be valid. It may be that conventional keyboards cannot effectively support the number of rapid access functions (with dedicated function keys) required for tower RAMP.

Conclusion

The most suitable keyboard replacement we see among currently available technologies is the electroluminescent touch panel. The unit is self-illuminated and compact as well as being fully programmable. Since the full surface is programmable, dedicated function keys, alternative QWERTY keyboards, and a display area for active function or keyboard inputs can be supported. Finally, with a software-defined key surface, future additions or deletions of functions could be accommodated with minor software amendments rather than hardware replacement.